Design and performance of a trigger collecting $Z \to b\bar{b}$ decays in $p\bar{p}$ collisions at $\sqrt{s} = 1.96\ TeV$

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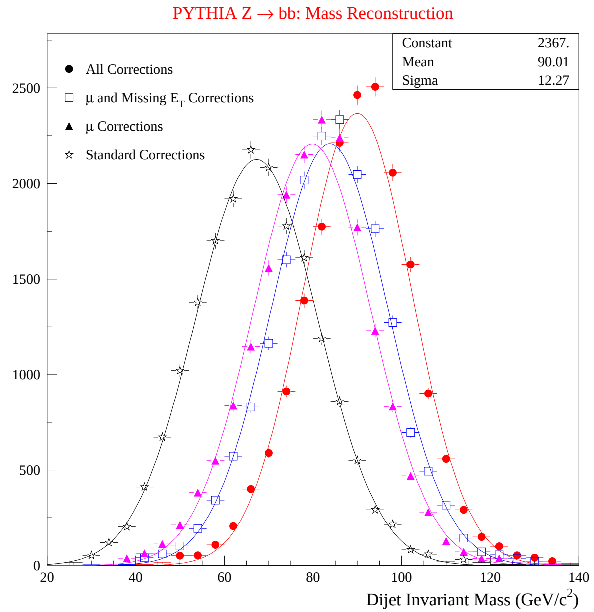
CDF Collaboration

Outline

- What can we learn from $Z \to b\bar{b}$?
- Past Searches at CDF
- Run-II detector
- The Silicon Detector and SVT device
- Signal and background
- A new trigger for $Z \to b\bar{b}$
- Conclusions

What can we learn from $Z \rightarrow b\bar{b}$?



hep-ph/0010338 HRWG

During Run-I, Monte Carlo based jet energy corrections (based on muon momentum, the $\not{E}_T$ and the jet charged fraction) allowed to obtain a better resolution on the $Z \rightarrow b\bar{b}$ mass peak.

In Run-II, we can also determine jet corrections using the Z peak itself as a calibration tool. It is then possible to:

- test and tune b-specific **jet corrections**;
- extract the **b-jet energy** scale and its uncertainty (see M. Baumgart [H13.009]);
- optimize **b-tagging algorithms**.

This information can be used in different analyses involving events containing b-jets, such as:

- **Associated Higgs production** (for $M_H < 130GeV$, $H \rightarrow b\bar{b}$).
- $t\bar{t}$ **production** ($tt \rightarrow WbWb$, mass measurement improvements).

Past Searches

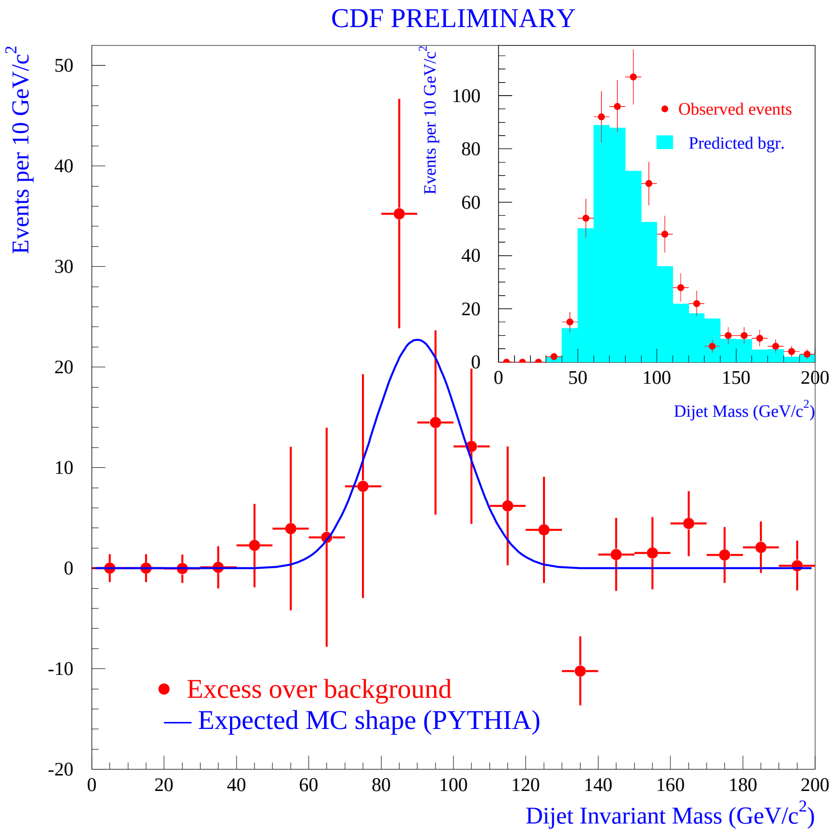


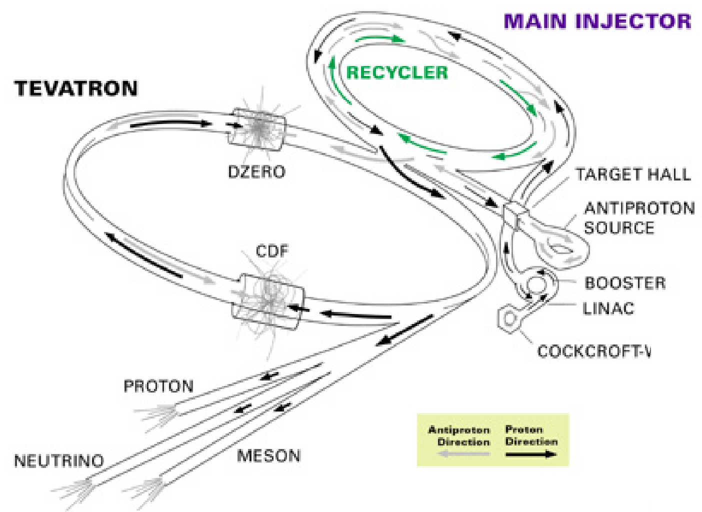
Fig. Results of the counting experiment
hep-ex/9806022

The $Z \rightarrow b\bar{b}$ process was for the first time isolated in hadron collisions during Run-I by the CDF-Collaboration.

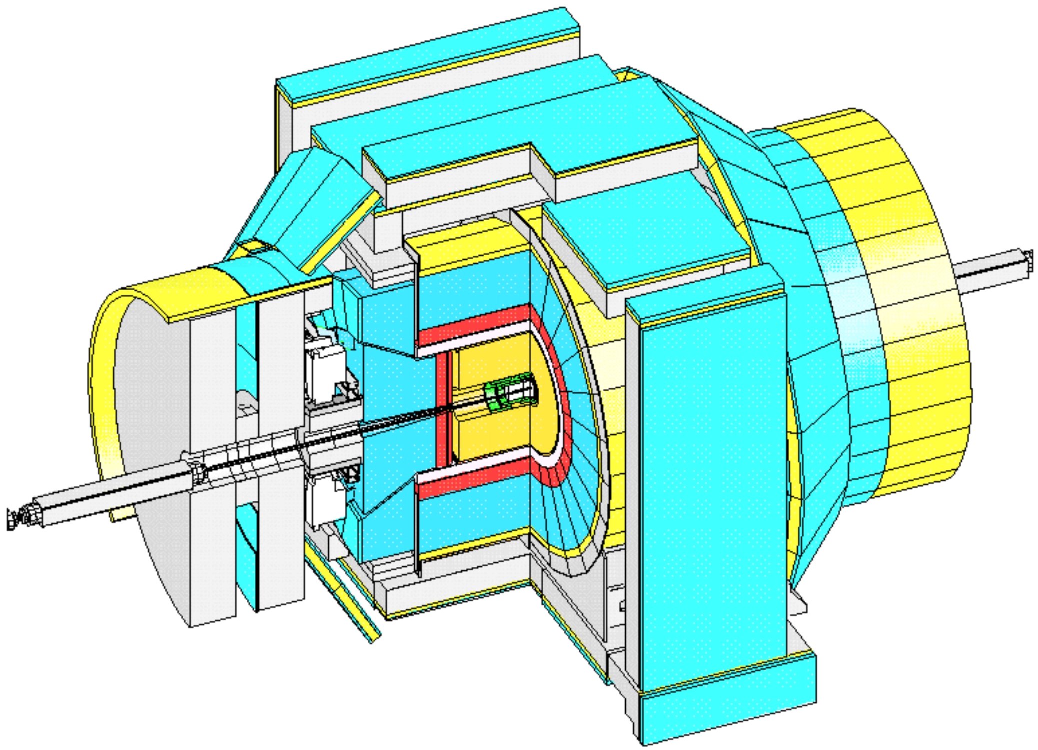
Events were collected using a muon based trigger and selected requiring:

- 2 jets with $E_T \geq 10\ GeV$ tagged as coming from a b-quark decay;
- $\Delta\phi_{jj} > 3\ rad$;
- $\Sigma_3 E_T < 10\ GeV$.

The CDF experimental complex



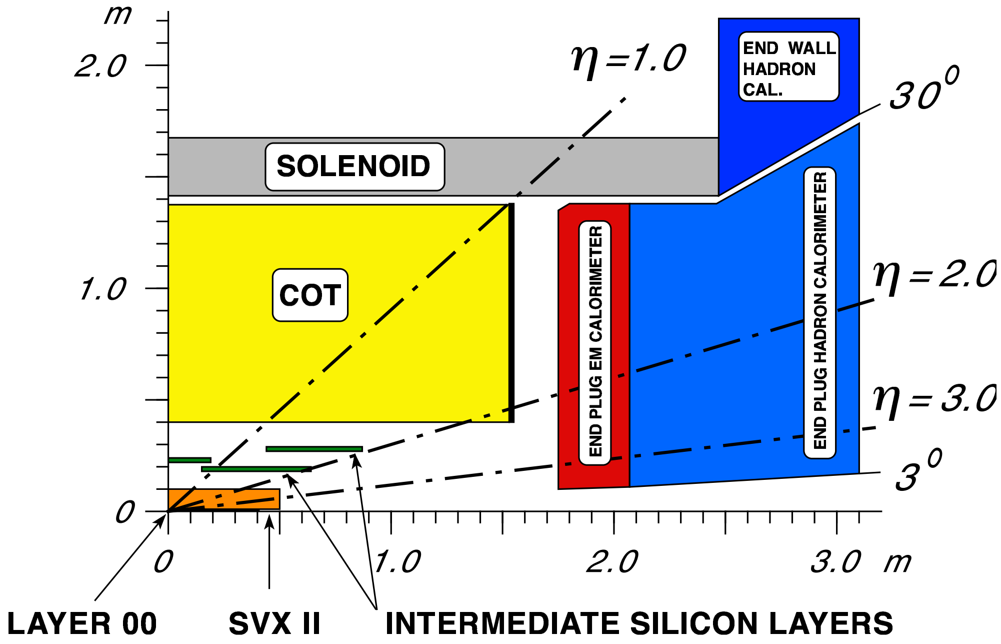
CDF is a multi-purpose detector specifically designed for the studies of $p\bar{p}$ interactions. Inside a large drift chamber is a 7-layers silicon detector crucial to detect secondary vertices from heavy flavour decays.



- $\sqrt{s} = 1.8\ TeV$ Run I
- $\mathcal{L}_{ist} \sim 10^{31}\ cm^{-2}s^{-1}$

- $\sqrt{s} = 1.96\ TeV$ Run II
- $\mathcal{L}_{ist} \sim 10^{32}\ cm^{-2}s^{-1}$ **(current peak** $\sim 4 \cdot 10^{31}$**)**

CDF Tracking Systems

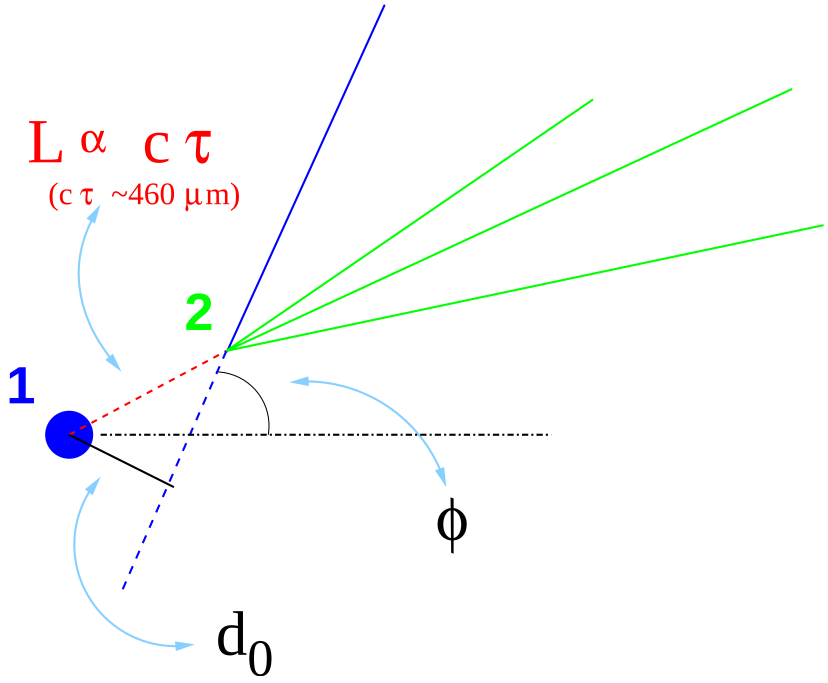


@ trigger system level:

- Level 1
  XFT: COT-based eXtreme Fast Tracker
- Level 2
  SVT: SVX-II-based Silicon Vertex Tracker

- SVX-II: 5+1 layers silicon detector
- ISL: 2-layers silicon detector
- COT:Central Drift Chamber
- EM: EM calorimeter
- HAD: HAD calorimeter

Silicon Vertex Tracker



Heavy quark decay generally produce **displaced tracks** with respect to the primary vertex

A good variable to look at in this context is the **impact parameter ($\mathbf{d_0}$)** defined, at trigger level, as the minimun distance between the track's helix and the beam line.

SVT uses the information of **XFT and SVX-II** devices to produce track parameter, $\mathbf{d_0}$, $\mathbf{P_T}$, ϕ_0 , in time for a level 2 trigger decision.

$(\sigma_{d_0} \sim 45\ \mu m,\ \sigma_\phi \sim 1\ mrad,\ \sigma_{P_T} \sim 0.3\% P_T^2)$

Signal vs Background

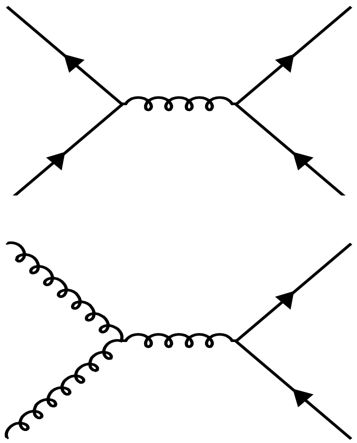
Signal

The signal consists in a pair of b's in the final state giving rise to a **couple of b-jets**.

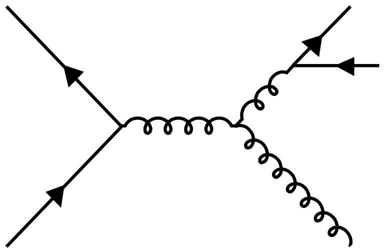
Background

Principal background is rappresented by processes yielding two jets in the final state. The **long life times of b's** can be used to **select** only the **heavy flavour production processes** by means of the impact parameter of charged tracks.

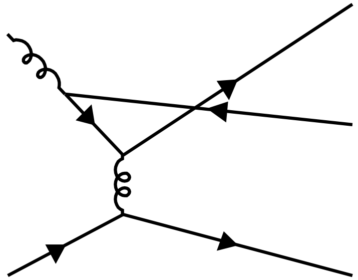
Other $b\bar{b}$ sources are the following:



$b\bar{b}$ direct production



$b\bar{b}$ from gluon splitting



$b\bar{b}$ flavour excitation

The new Trigger for $Z \to b\bar{b}$ events

During Run I, to see $Z \to b\bar{b}$ decays, we triggered on **MUONS**.

In Run II, with **SVT**, we trigger on the impact parameter of charged tracks.

This allows to collect b-enriched dijet events without μ energy bias.

The trigger requirements develop through all the trigger system levels, but essentially, **we select events containing:** ▶▶

Z_BB Trigger ($\sigma_{trg} \sim 23\ nb$)

- **2 jets with $E_T > 10$ GeV**
- **1 trk with $P_T > 2.5$ GeV**
- **1 trk with $P_T > 3.5$ GeV**
- **both tracks with 150 μm $< |d_0| <$ 1 mm**
- **$\Delta\phi_{tt} > 150°$**

Efficiency on signal $\sim$ 1%

Level 1

$\sigma_{level\ 1} \sim 11000\ nb$

$R_{level\ 1} \sim 440\ Hz$

$@\ 4 \cdot 10^{31}\ cm^{-2}s^{-1}$

- two tracks with $P_T > 2\ GeV$ reconstructed by the e**X**treme **F**ast **T**racker using drift chamber information.
- $\Delta\phi_{tt} > 150°$
- two central calorimetric towers with $E_T > 5\ GeV$

Level 2

$\sigma_{level\ 1} \sim 50\ nb,\ (2\ Hz)$

- two $P_T > 2.5\ GeV$ tracks reconstructed with both silicon detector and level 1 tracks information (**SVT**).
- confirmation of the Level 1 $\Delta\phi_{tt}$ cut.

Level 3

$\sigma_{level\ 1} \sim 23\ nb,\ (1\ Hz)$

- confirmation of Level 2 requirements
- two **jets** with $E_T > 10\ GeV$.

Conclusions

Right now $\sim$ **670,000 events** (after good run requirements) have been collected with the described trigger.

According to the actual integrated luminosity $\sim$ **30 pb^{-1}** we expect **300 $\div$ 400 Z's** in the triggered sample.

	σ_{BKG} [nb]	$\sigma_Z \cdot BR(Z \to b\bar{b})$ [nb]	**S/N ratio**
before trg	-	1.2	-
level 1	11000	0.48	$\mathbf{4 \cdot 10^{-5}}$
level 2	50	0.015	$\mathbf{3 \cdot 10^{-4}}$
level 3	23	0.013	$\mathbf{5.6 \cdot 10^{-4}}$

Plans:

Add a level 3 tagging algorithm `in order to increase the efficiency on signal events and increase the S/N ratio at this level.`

Level 2

L2 band width = 300 Hz

- two SVT tracks with $P_T > 2.5\ GeV$, $|d_0| > 150\ \mu m$
- $\Delta\phi_{tt} > 150°$

$\sigma_{level\ 2} \sim 50\ nb,\ (2\ Hz)$

Level 3

L3 band width = 70 Hz

- two jets with $E_T > 10\ GeV$, $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$
- one COT+SVT track with $P_T > 2.5$, $|d_0| > 150\ \mu m$, $|\eta| < 1.2$
- one COT+SVT track with $P_T > 3.5$, $|d_0| > 150\ \mu m$, $|\eta| < 1.2$
- $\Delta\phi_{tt} > 150°$

$\sigma_{level\ 3} \sim 23\ nb,\ (1\ Hz)$